

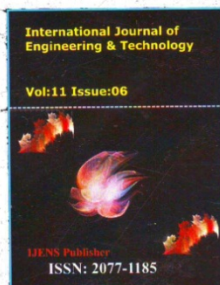
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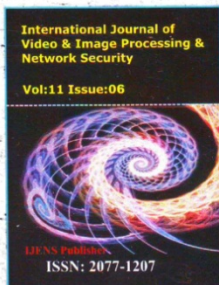
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Volume: 11, Issue: 06

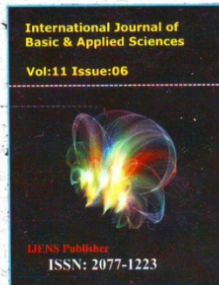
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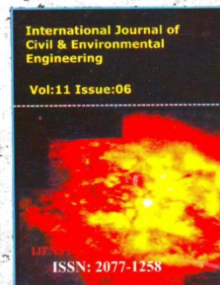
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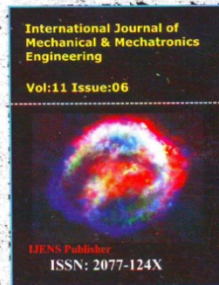
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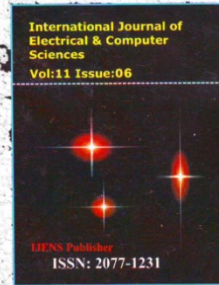
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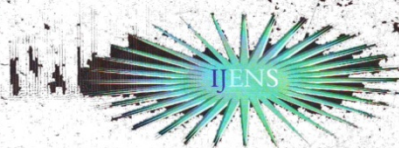


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**IJENS Publishers
December 2011**

The Effect of Outer Room Design on the Development of Thermal Comfort Concept in Minahasa Stilt House Industrial Production

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Abstract

The aim of the study was to describe and analyze; 1) the boarding room thermal comfort of Minahasa stilt house industrial production which has been developed by the owner, viewed from the effect of outer room design element; 2) the residents' perception on the thermal comfort of the boarding room; 3) to develop the concept of thermal comfort of the Minahasa stilt house industrial production.

The study was conducted at Kleak sub-district, in Manado, North Sulawesi, Indonesia. The study was a field survey by doing systematic observation at 159 units of analysis and 355 respondents of residents'. The data were analyzed statistically assisted by excel program using table of frequency and cross tabulation followed by qualitative analysis.

The results of the study indicate that 1) the outer room design has a significant effect on thermal comfort; 2) residents' perception 93.7% according to measurement result; 3) the development of thermal comfort requires the availability of open space of evergreen yard.

Key words: stilts house, thermal comfort, outer room design element, open space of evergreen yard.

I. INTRODUCTION

In general the shape of stilts house can assure the most efficient cross ventilation so that thermal comfort can occur naturally. Minahasa stilt house industrial production is still of community great interest up to now since its simple shape and flexibility in room arrangement and it is easy to be taken apart and put back together (knock down).

The present phenomena, many people buy the stilt house to be used as a boarding house. This is due to a great demand of boarding room for new students' accommodation. The need is a business opportunity for the community around the campus. The continuous increase number of new students annually makes the business of boarding house a promising. This has formed the community cognition to make use of 100% of their house area to be a boarding room. Renovation of old houses and building new ones for business is mushrooming around the campus area.

One of the regions located at the educational area is Kleak sub-district. Today Kleak sub-district has become a highly populated area

with the distance between buildings is < 1 m. Wind flow is difficult at this area full of high density buildings, and the temperature at the area becomes hotter. This condition is worsened by the lack of private evergreen open space and public evergreen open space at the housing compound of Kleak sub-district. The outdoor high temperature can increase temperature in the boarding rooms of the students. According to [37], very hot temperature can have a direct effect on brain, brain function is not maximal, low working ability, and someone can be more emotional. These phenomena can have a bad effect on students who are studying. Students as an intellectual candidate will determine the faith of the nation in the future. Their study can be disturbed because their residence is unhealthy and has thermal discomfort. On the other side, thermal comfort is important naturally as an effort to save electric power.

The aims of the study were (1) to describe and analyze the thermal comfort of boarding house room in Minahasa stilt house industrial production that has been developed by the owner viewed from the effect of outer room design: a) building orientation to the sun and wind; b) house location to topography; c) distance between buildings; d) open space of evergreen yard; (2) to describe and analyze residents perception on the thermal comfort of their room; and (3) to develop the thermal comfort concept of Minahasa stilt house industrial production.

II. REVIEW OF THE LITERATURE

Thermal comfort is defined by [13], as a condition in which someone expresses the feeling of comfort to his thermal environment. [12], [13], [30], [31], [35], [40], [43] states that comfortable environment thermally is affected by 4 environmental conditions and mechanism of the loss of heat from human body. The four environmental conditions are 1) air temperature; 2) relative humidity; 3) air velocity; and 4) mean radiant temperature(MRT). According to [16], [19], [20], [21], [37], thermal comfort is a natural factor affecting the human beings directly. The dominant natural factors are: (1) air temperature; (2) air humidity; and (3) wind movement.

According to [6], [23], [43], [55], [62], [64], the three natural factors are stimuli received by human sense which then produce perception on thermal comfort around them. Based on the perception, the individual will do a certain act or will take a position. If the environmental temperature is perceived as beyond the optimal limits that is too hot or too cold, then the individual will feel stress or adapt himself to his environmental condition(coping behavior). The reaction to self adjustment from a certain environment with certain temperature to other environment with different temperature is called acclimatization[43] is of the opinion that there is no significant temperature difference at comfort level perceived by male or female, young or old,

the difference only lies at the way one dressed and activity of each individual. The idea is different from [27], [31], [63]. They are of the opinion that perception and ability to adaptation of each individual is affected by gender, age, origin, race and cultural background. The ideas are disputed by [64] because the last research has found no evidence that native/race affects perception on comfort. Human beings have an ability to adapt to climate condition (acclimatization) accordingly. Normally, someone who comes to a different climate environment can adapt himself in 2 weeks. In general female likes environment which is 1°C warmer than male, whereas old aged people like warmer environment.

From the explanation above we can conclude that thermal comfort is a thermal condition felt by human body and is perceived by each individual. Thermal comfort can also be conditioned by modifying the environment and objects around its architecture. To make the environment to be more comfort maximally, it can be done naturally and unnaturally [18], [19], [26], [29], [36], [37], [38]. In this discussion the focus is on the natural thermal comfort achievement only. The main principle of natural thermal comfort is the empowerment of environmental potential to cooling process or air refreshment. [12], [35], [36], [38], [40], [42] is of the opinion that by conditioning the aspects of building design: 1) inner room(room shape, room arrangement, room

volume), 2)construction, 3)material, 4)cross ventilation, 5)protection of room from the sun, 6) humidity reduction, 7)heat isolation and the aspect of site/outer room design: 1) appropriate building orientation to the sun and wind; and 2) plant a lot of vegetation can affect the interior climate, lower the room temperature to be comfortable without using mechanical equipment. [37], is of the same opinion with [12], [35], [36], [38], [40], [42], states that there are 3 strata of planning approach that must be done to get sustainable comfortable temperature: (1)room protection system and heat avoidance by minimizing heat in building with strategies: using shadow, orientation, color, vegetation, partition, let the day light in, and control internal heat sources; (2)passive cooling system by minimizing not only heat but also the use of ventilation; (3)the use of mechanical equipment which can only be used if the two cooling processes mentioned above are not maximal yet; (4)site design/outer room. [18] point out that there are 2 types of refreshment processes: passive air cooling and active air cooling. The passive air cooling can be achieved by three ways: 1)protection to the sun by arrangement of buildings (building orientation to the sun and wind, building location to topography, distance between buildings), and arrangement of shading vegetation; 2) permanent sun protection(sun shading), and 3) sun blind for moving sun/ window pane; and the active air cooling is achieved by cross ventilation.

Based on the explanation of the literature review, there are 2 conclusions can be drawn: first, based on [6], [12], [13], [16], [19], [20], [21], [23], [27], [30], [31], [35], [37], [40], [43], [55], [62], [63], [64] ideas, it can be concluded that thermal comfort is an environmental condition felt by human beings and there are 2 factors affecting it: (1) **climate factor** (physical environment), air temperature (T), wind velocity (V), air relative humidity (RH) and (2) **individual perception factor**(non-physical environment): individual health condition, human activity, and clothing (Clo). The second conclusion is based on [12], [18], [19], [26], [29], [35] [36], [37], [38] [40], [42] ideas, it can be concluded that thermal comfort can be achieved by conditioning/designing the building and site/outer room, **The building design** : 1) inner room (room shape, room arrangement and room volume), 2) building envelope (opening-inlet and outlet- and closing), **the site design/outer room design** (building orientation to the sun and wind, distance between buildings, house location to topography and open space of evergreen yard).

Based on the research problems, more explanation about site design/outer room in literature review will be discussed.

1) Building orientation. According to [7], [8], [12], [16],[19], [37], [38], [40], [41], [43], the shortest side of the building should be oriented toward the sun rises and the sun sets. This is

important when the facade hits by the sun, heat radiation will occur that can increase room temperature. The longest side of the building should be oriented toward the wind flow, the position which can make cross ventilation occur for 24 hours without mechanical equipment.

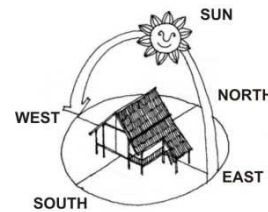


Fig.1. The best building orientation is toward the east and west or toward the sun [20]

2) House location to topography. Topography of the earth's surface is different, some flat, sloping, waving causing the difference of wind velocity & creates different patterns of wind flow on the earth's surface (Fig 2) [20], [57], [19].

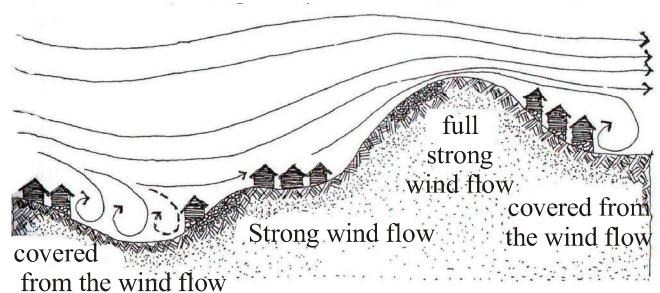


Fig.2. The effect of topographical constraint, building on wind movement [20]

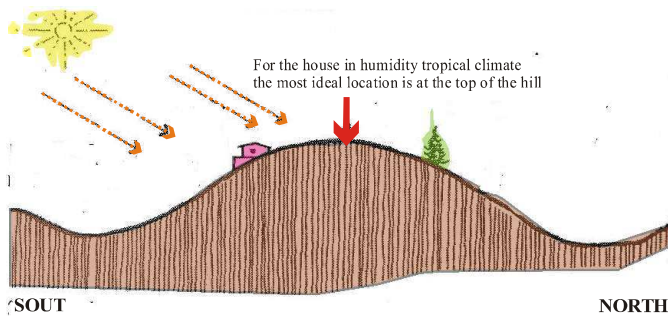


Fig. 3. For the house in humidity tropical climate, the most ideal location is at the top of the hill [35].

According to [35], in order to obtain thermal comfort at the time of occupying the house, site location/house site must pay attention to climate condition and its topography.

3) Distance between buildings

Distance between buildings determines the air movement in environment/outer room. According to [21] and [58] a high density area in general will have higher environmental temperature than area with low density. Although it has also to be put into account the wind velocity condition, vegetation density, height and orientation toward the sun.

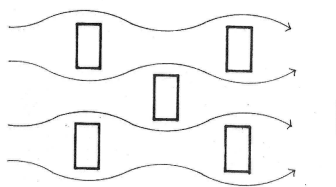


Fig. 4. Appropriate distance between buildings and unparallelled arrangement supports the natural ventilation [35]



Fig.5. Tocamacho, Honduras has a hot and humid climate of which the building arrangement is far apart [35]

Building arrangement has an effect on wind movement. The building arrangement blocking the air movement is due to the constraint that can hamper the wind movement (Fig. 6a). Ordered building arrangement is the form of grid with the road crosses perpendicularly can increase wind velocity. The potential of this velocity can be used for ventilation in the building (Fig. 6b) [21].

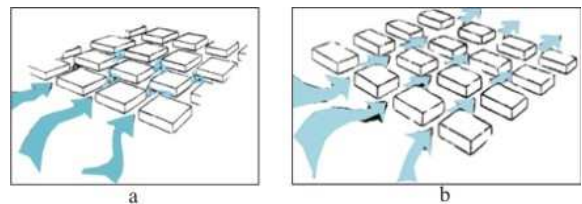


Fig. 6. Building arrangement affecting the wind movement in an environment [21]

4) Evergreen Open Space

Evergreen open space is an open space covered by vegetation is not included open space covering with paving block. Evergreen open space will play a great role in creating thermal comfort because: 1) it filters solar heat radiation directly on it so that it can lower the

air temperature of the environment and further the air temperature will affect the room air temperature. 2) it produces fresh and healthy air since it has a lot of O_2 . Vegetation of 1 hectare can produce oxygen 600 kg/day, neutralize carbon dioxide 900 kg/day, filter ash up to 85% and can lower temperature up to 4°C [19], [40], [41], [68], [70], [74], [80]. The test result indicates that the air temperature on the asphalt close to shaded grass is 52°C whereas on the grass is only 35°C . The difference 17°C has a great effect on the lowering of inner room temperature;

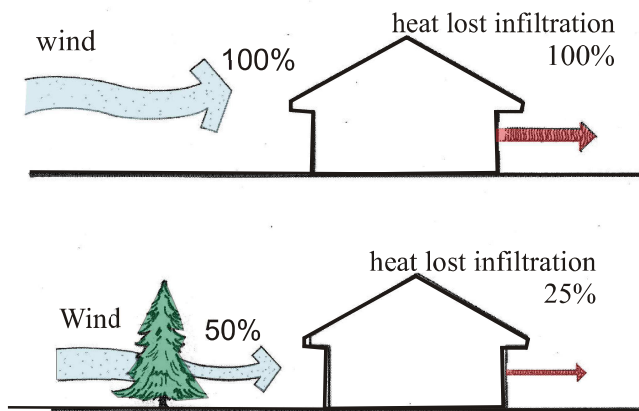


Fig 7. Heat lost infiltration

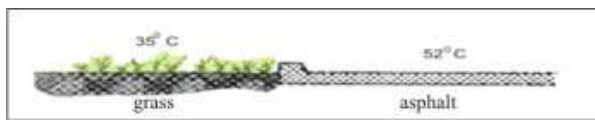


Fig. 8. Air on the asphalt material will be hotter than the air on the grass [35].

3) control wind flow by obstructing, filtering, directing or turning the wind [35], [36], [37], [38].

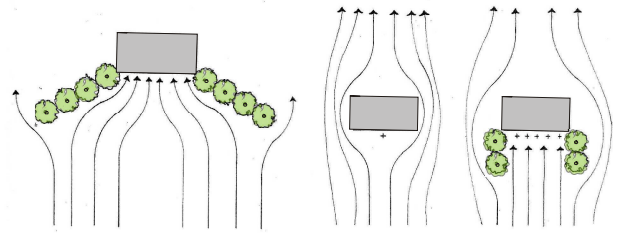


Fig 9. The vegetation can control wind flow by obstructing, filtering, directing or turning the wind [35].

The ideal proportion of land is 60/40 that is 60% building and 40% evergreen open space. This ideal proportion makes the creation of good cross ventilation [26], [41], [48], [49], [50], [51].

III. RESEARCH METHOD

The study was a field survey by conducting systematic observation to 159 units of analysis. The units of analysis are all population (full sampling) that is 159 Minahasa stilt houses industrial production function as boarding houses and have been developed by the owners. Measurement was done simultaneously for 1 month (November 2010) from 7:00 A.M. to 3:59 P.M. for room setting, open doors and windows. The 159 houses have 3 types variation of room arrangement (fig.10).

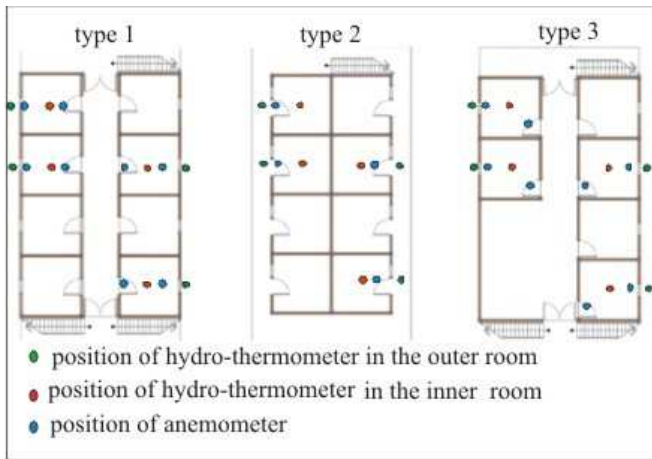


Fig. 10. The horizontal position of equipment, the hydro-thermometer and anemometer were put in the room of analysis unit (The Writer, 2011).



Fig. 11. The placement of equipment vertically (The Writer, 2011).

Data on temperature measurement, humidity used in/out thermo-hygrometer, wind velocity used anemometer, building used meter, determination of wind flow used compass.



Hydro-thermometer

anemometer



meter

compass

Fig. 12. Measurement equipment used in the study (The Writer, 2011)

Data on temperature measurement, humidity and wind velocity were analyzed by using psychometric diagram and effective temperature diagram to obtain the value of effective temperature (fig 13&14). The scale of thermal comfort level measurement used was based on effective temperature using interval scale categorized as follows: *cool uncomfortable* <20 ET, *cool comfortable* 20⁺-23 ET, *warm comfortable* 23⁺ - 26 ET, *warm uncomfortable* 26⁺ ET. Data on residents' perception were obtained through interview to 355 respondents. Measurement scale for the residents' perception was categorized as follows: *cool uncomfortable* means too cold so that the respondents was shivering, ill and have to wear several clothes, *cool comfortable* means the respondents can do activity in the room comfortably including taking a nap,

not sweat, *warm comfortable* means the respondents feel hot but can do all activities comfortably, little sweat when doing the activities, cannot take a nap, *warm uncomfortable* means the body feels hot, sweating all the time, cannot do activities in the room calmly and comfortably).

In order to determine students as respondents, the samples were based on disproportionate stratified random sampling. This technique was done because the population of the stilt houses residing by the students is less proportional.

The stilt houses were divided into 3 types of room arrangement: 111 type 1 houses, 8 type 2 houses, 40 type 3 houses. All 8 type 2 houses were taken as samples because the number is too small compared to type 1 houses and type 3 houses. Measurement of each house was done in 8 rooms in which each resident was taken as population, so that the number of respondents was 64 students for 8 houses. The number of population for 111 houses and 40 houses was 1208 students. If the samples were taken based on *Krejcie table*, the number of samples was 291. Therefore the total samples were 355 respondents.

The data were analyzed statistically assisted by excel program through tables of frequency and cross tabulation followed by qualitative method using inductive analysis

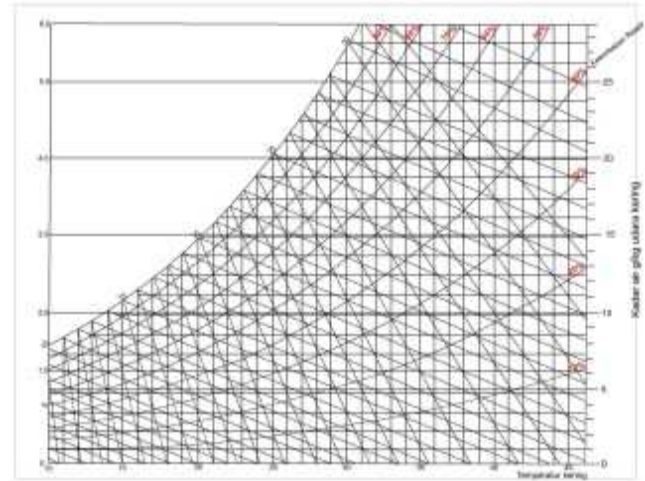


Fig. 13. Psychrometric diagram

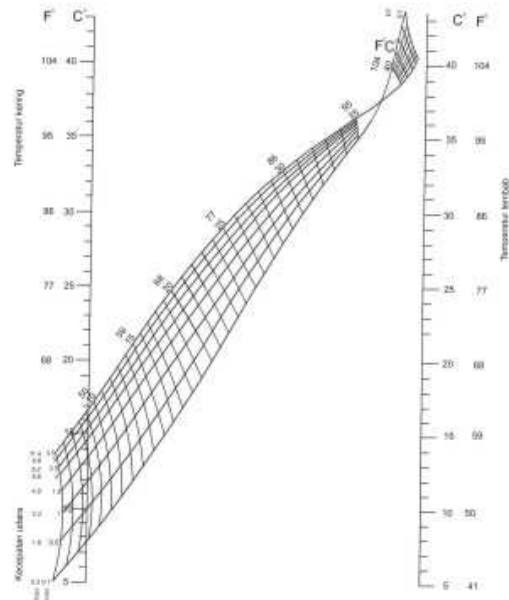


Fig. 14. Effective temperature diagram

IV. RESULTS AND DISCUSSION

The study was conducted at Kleak sub-district, Manado, North Sulawesi. Kleak sub-district borders directly with education area of Sam Ratulangi University. The topographical condition is wavy and hilly with the highest point is 60 m above the sea level.

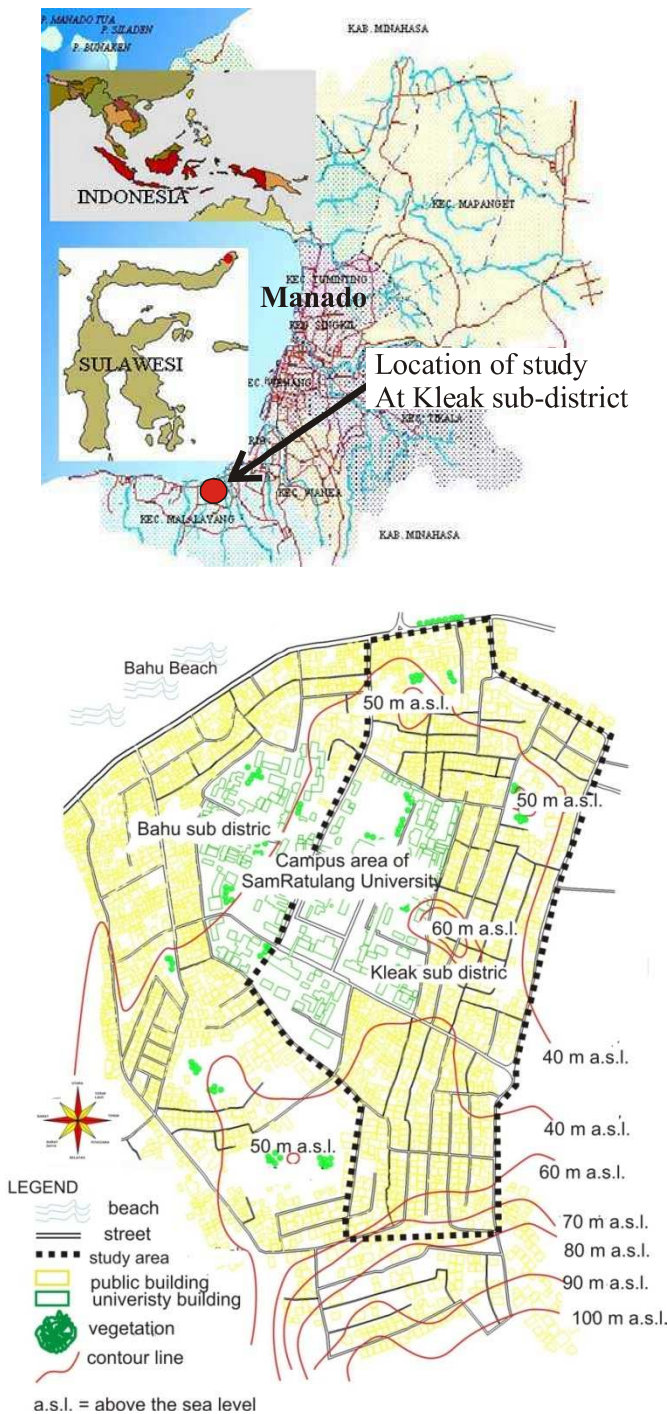


Fig. 15. Map of Kleak Sub-district

A. Thermal Comfort Viewed From Building Orientation Toward the Sun and Wind.

TABLE I.
MEASUREMENT OF THERMAL COMFORT LEVEL IN
HOUSES WITH ORIENTATION TOWARD THE SUN AND
WIND.

| Thermal comfort level (ET) | Building Orientation | | | | | |
|------------------------------|-------------------------|-------|-------------------------|-------|-------|--------|
| | A. Toward the wind(N-S) | | B. Toward the sun (E-W) | | Total | |
| | n ₁ | % | n ₂ | % | n | % |
| 07:00 AM-09:59 AM | | | | | | |
| cool uncomfortable < 20 | 0 | 0,00 | 0 | 0,00 | 0 | 0,00 |
| cool comfortable 20+ s.d 23 | 0 | 0,00 | 0 | 0,00 | 0 | 0,00 |
| warm comfortable 23 + s.d 26 | 26 | 16,35 | 13 | 8,18 | 39 | 24,53 |
| warm uncomfortable 26+ | 69 | 43,40 | 51 | 32,08 | 120 | 75,47 |
| Total | 95 | 59,75 | 64 | 40,25 | 159 | 100,00 |
| 10:00AM -00:59 PM | | | | | | |
| cool uncomfortable < 20 | 0 | 0,00 | 0 | 0,00 | 0 | 0,00 |
| cool comfortable 20+ s.d 23 | 0 | 0,00 | 0 | 0,00 | 0 | 0,00 |
| warm comfortable 23 + s.d 26 | 0 | 0,00 | 10 | 6,29 | 10 | 6,29 |
| warm uncomfortable 26+ | 95 | 59,75 | 54 | 33,96 | 149 | 93,71 |
| Total | 95 | 59,75 | 64 | 40,25 | 159 | 100,00 |
| 01:00 PM -03:59 PM | | | | | | |
| cool uncomfortable < 20 | 0 | 0,00 | 0 | 0,00 | 0 | 0,00 |
| cool comfortable 20+ s.d 23 | 0 | 0,00 | 0 | 0,00 | 0 | 0,00 |
| warm comfortable 23 + s.d 26 | 0 | 0,00 | 5 | 3,14 | 5 | 3,14 |
| warm uncomfortable 26+ | 95 | 59,75 | 59 | 37,11 | 154 | 96,86 |
| Total | 95 | 59,75 | 64 | 40,25 | 159 | 100,00 |

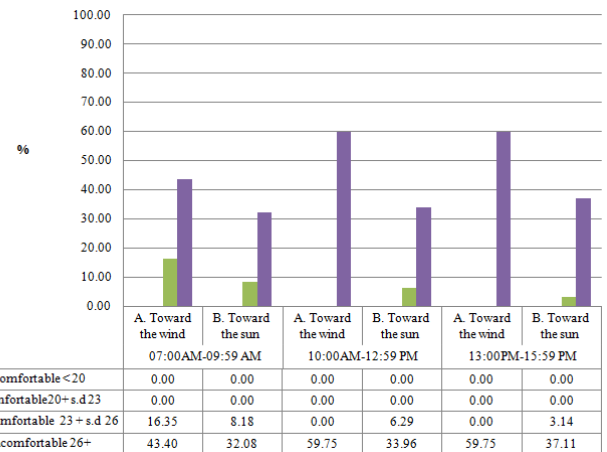


Fig.16. Diagram of thermal comfort level in houses with orientation toward the sun and wind.

Houses oriented toward the wind (95 houses), 26 of them (16.35%) are warm comfortable in the morning (from 7:00 to 9:59 A.M.) but since there is no space shading such as vegetation at the east

and west sides of the house which can get a lot of direct sun light, the evergreen open space < 40% and the distance between buildings < 4,5 m, the houses are uncomfortable during the day (from 10:00 A.M. to 03:59 P.M.).



Fig. 17. Twenty two warm comfortable houses oriented toward the wind during measurement at 7:00 - 9:59 A.M.

There are 13 warm comfortable houses (8.18%) oriented toward the sun in the morning (7:00 A.M. to 9:59 A.M.), 10 warm comfortable houses (6.29%) during the day (10:00 A.M.– 00:59 P.M.) and 5 warm comfortable houses (3.14%) in the afternoon (01:00 P.M. – 03:59 P.M.) Houses which are uncomfortable are those evergreen open space

< 40%, lie at the sloping topographical area and the distance between buildings is < 4 m.



Fig. 18. Warm comfortable houses oriented toward the sun (13 houses) during measurement at 7:00 A.M. – 9:59 A.M.

B. Thermal Comfort Viewed from the Site at Topographical Area

TABLE II.

MEASUREMENT OF THERMAL COMFORT LEVEL OF HOUSES AT SLOPING HILL SITE AND FLAT AREA

| Thermal comfort level (ET) | Site topographical area | | | | | |
|------------------------------|-------------------------|-------|-----------------|-------|-------|--------|
| | A. at Sloping hill area | | B. at flat area | | Total | |
| | n ₁ | % | n ₂ | % | n | % |
| 07:00 AM-09:59 AM | | | | | | |
| cool uncomfortable < 20 | 0 | 0,00 | 0 | 0,00 | 0 | 0,00 |
| cool comfortable 20+ s.d 23 | 0 | 0,00 | 0 | 0,00 | 0 | 0,00 |
| warm comfortable 23 + s.d 26 | 15 | 9,43 | 24 | 15,09 | 39 | 24,53 |
| warm uncomfortable 26+ | 2 | 1,26 | 118 | 74,21 | 120 | 75,47 |
| Total | 17 | 10,69 | 142 | 89,31 | 159 | 100,00 |
| 10:00AM-00:59 PM | | | | | | |
| cool uncomfortable < 20 | 0 | 0,00 | 0 | 0,00 | 0 | 0,00 |
| cool comfortable 20+ s.d 23 | 0 | 0,00 | 0 | 0,00 | 0 | 0,00 |
| warm comfortable 23 + s.d 26 | 3 | 1,89 | 7 | 4,40 | 10 | 6,29 |
| warm uncomfortable 26+ | 14 | 8,81 | 135 | 84,91 | 149 | 93,71 |
| Total | 17 | 10,69 | 142 | 89,31 | 159 | 100,00 |
| 01:00 PM-03:59 PM | | | | | | |
| cool uncomfortable < 20 | 0 | 0,00 | 0 | 0,00 | 0 | 0,00 |
| cool comfortable 20+ s.d 23 | 0 | 0,00 | 0 | 0,00 | 0 | 0,00 |
| warm comfortable 23 + s.d 26 | 3 | 1,89 | 2 | 1,26 | 5 | 3,14 |
| warm uncomfortable 26+ | 14 | 8,81 | 140 | 88,05 | 154 | 96,86 |
| Total | 17 | 10,69 | 142 | 89,31 | 159 | 100,00 |

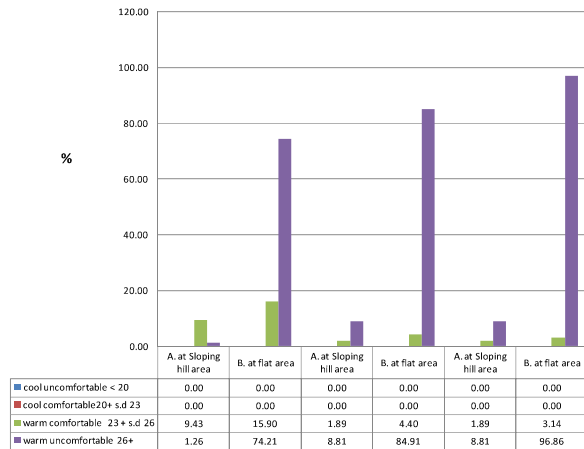


Fig. 19. Diagram of thermal comfort level of houses at sloping hill site and flat area

C. Thermal Comfort Viewed from Distance between Buildings.

TABLE III.

MEASUREMENT OF THERMAL COMFORT LEVEL OF HOUSES WITH THE DISTANCE BETWEEN BUILDINGS <4.5 M AND 4.5+M.

| Distance Between Buildings | | | | | | |
|------------------------------|----------------|-------|----------------|-------|-------|--------|
| Thermal comfort level (ET) | A. 4.5+m | | B. < 4.5m | | Total | |
| | n ₁ | % | n ₂ | % | n | % |
| 07:00 AM-09:59 AM | | | | | | |
| cool uncomfortable < 20 | 0 | 0,00 | 0 | 0,00 | 0 | 0,00 |
| cool comfortable 20+ s.d 23 | 0 | 0,00 | 0 | 0,00 | 0 | 0,00 |
| warm comfortable 23 + s.d 26 | 32 | 20,13 | 7 | 4,40 | 39 | 24,53 |
| warm uncomfortable 26+ | 6 | 3,77 | 114 | 71,70 | 120 | 75,47 |
| Total | 38 | 23,90 | 121 | 76,10 | 159 | 100,00 |
| 10:00 AM-00:59 PM | | | | | | |
| cool uncomfortable < 20 | 0 | 0,00 | 0 | 0,00 | 0 | 0,00 |
| cool comfortable 20+ s.d 23 | 0 | 0,00 | 0 | 0,00 | 0 | 0,00 |
| warm comfortable 23 + s.d 26 | 10 | 6,29 | 0 | 0,00 | 10 | 6,29 |
| warm uncomfortable 26+ | 28 | 17,61 | 121 | 76,10 | 149 | 93,71 |
| Total | 38 | 23,90 | 121 | 76,10 | 159 | 100,00 |
| 01:00 PM-03:59 PM | | | | | | |
| cool uncomfortable < 20 | 0 | 0,00 | 0 | 0,00 | 0 | 0,00 |
| cool comfortable 20+ s.d 23 | 0 | 0,00 | 0 | 0,00 | 0 | 0,00 |
| warm comfortable 23 + s.d 26 | 5 | 3,14 | 0 | 0,00 | 5 | 3,14 |
| warm uncomfortable 26+ | 33 | 20,75 | 121 | 76,10 | 154 | 96,86 |
| Total | 38 | 23,90 | 111 | 76,10 | 159 | 100,00 |

Houses with distance between buildings 4.5⁺m [the distance between buildings is the front part of the building is 3 m, rear and left-right sides of the

building is minimal 1.5⁺m (3 m + 1.5 = 4.5 m)] should assure adequate flow of wind to lower the temperature and drives away humid air in the room. But there are 6 houses with distance between building 4.5⁺m have been warm uncomfortable in the morning. This uncomfortable condition is due to the site of the houses is covered by concrete and asphalt so that the temperature around the houses increases.

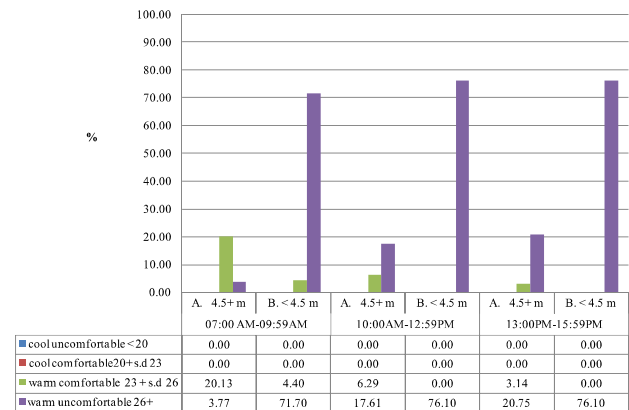


Fig. 20. Diagram of thermal comfort level of houses with distance between buildings < 4.5 m and 4.5⁺ m



Fig. 21. Six warm uncomfortable houses with distance between buildings 4.5⁺m

There are 7 houses (4.40%) with distance between buildings < 4.5 m is at the level of warm comfortable in the morning (7:00 A.M. – 9:59 A.M.) This happens since the houses are at the top of the hill toward the beach so that the houses get enough strong wind flow. This comfort condition only occurs in the morning because it is influenced by the sea wind. During the day (10:00 A.M. – 03:59 P.M.) when the earth's temperature is maximum due to the sun position in the sky is perpendicular over the houses, the thermal comfort becomes uncomfortable.

The measurement of houses R111 and R112 with the distance between buildings 4.5^+m , shows that 2 houses are at the level of warm uncomfortable. This condition occurs because the topography of the house location is beyond the hill, so that the houses are covered from the wind flow. The two houses have to use air cooling machine (Fig. 23&24).

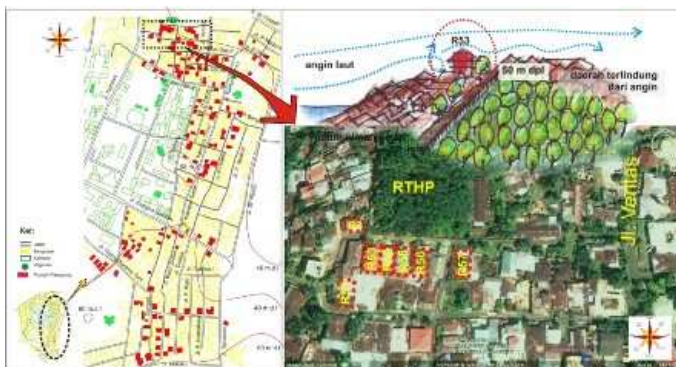


Fig. 22. Seven warm comfort houses with distance between buildings < 4.5 m

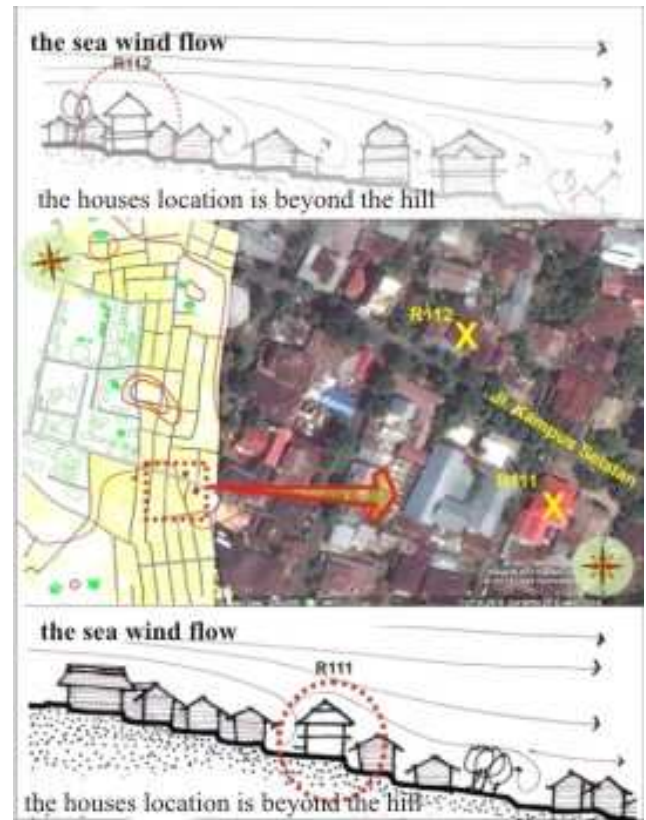


Fig. 23. House location R111 and R112 toward topography



Fig. 24. Stilt houses R111 and R112 using air condition

D. Thermal Comfort Viewed from Evergreen open yard

TABLE IV.

MEASUREMENT OF THERMAL COMFORT LEVEL OF
HOUSES WITH EVERGREEN OPEN HOUSES YARD 40%+ &
EVERGREEN OPEN HOUSES YARD <40%

| Evergreen Open Yard | | | | | | |
|------------------------------|----------------|-------|----------------|-------|-------|--------|
| Thermal comfort level (ET) | A. 40% + | | B. < 40% | | Total | |
| | n ₁ | % | n ₂ | % | n | % |
| 07:00 AM - 09:59AM | | | | | | |
| cool uncomfortable < 20 | 0 | 0,00 | 0 | 0,00 | 0 | 0,00 |
| cool comfortable20+ s.d 23 | 0 | 0,00 | 0 | 0,00 | 0 | 0,00 |
| warm comfortable 23 + s.d 26 | 32 | 20,13 | 7 | 4,40 | 39 | 24,53 |
| warm uncomfortable 26+ | 0 | 0,00 | 120 | 75,47 | 120 | 75,47 |
| Total | 32 | 20,13 | 127 | 79,87 | 159 | 100,00 |
| 10:00 AM - 00:59 PM | | | | | | |
| cool uncomfortable < 20 | 0 | 0,00 | 0 | 0,00 | 0 | 0,00 |
| cool comfortable20+ s.d 23 | 0 | 0,00 | 0 | 0,00 | 0 | 0,00 |
| warm comfortable 23 + s.d 26 | 10 | 6,29 | 0 | 0,00 | 10 | 6,29 |
| warm uncomfortable 26+ | 22 | 13,84 | 127 | 79,87 | 149 | 93,71 |
| Total | 32 | 20,13 | 127 | 79,87 | 159 | 100,00 |
| 01:00 PM -03:59 PM | | | | | | |
| cool uncomfortable < 20 | 0 | 0,00 | 0 | 0,00 | 0 | 0,00 |
| cool comfortable20+ s.d 23 | 0 | 0,00 | 0 | 0,00 | 0 | 0,00 |
| warm comfortable 23 + s.d 26 | 5 | 3,14 | 0 | 0,00 | 5 | 3,14 |
| warm uncomfortable 26+ | 27 | 16,98 | 127 | 79,87 | 154 | 96,86 |
| Total | 32 | 20,13 | 127 | 79,87 | 159 | 100,00 |

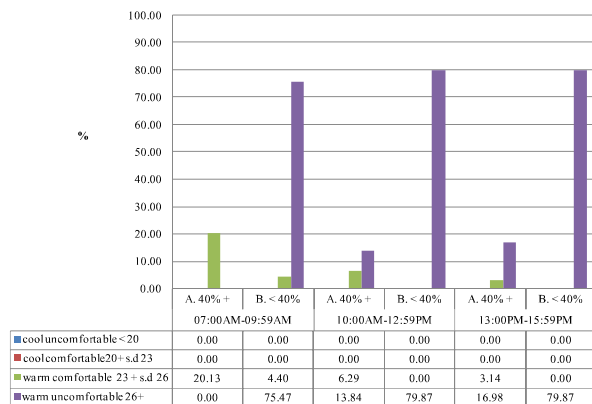


Fig. 25. Diagram of thermal comfort level of houses with open space of evergreen yard 40%+ and open space of evergreen yard <40%

The number of evergreen open houses yard more than 40% of land size are 32 houses (20.13%), all (100%) in the morning (7:00 A.M. – 9:59 A.M.) are at the level of warm comfortable. The houses which are warm uncomfortable until noon and afternoon are those lie at the dense populated residence at the valley. There are seven

houses have evergreen open space <40% but they are at the level of warm comfortable since they lie at the top of the hill where the environment are green (fig. 21).

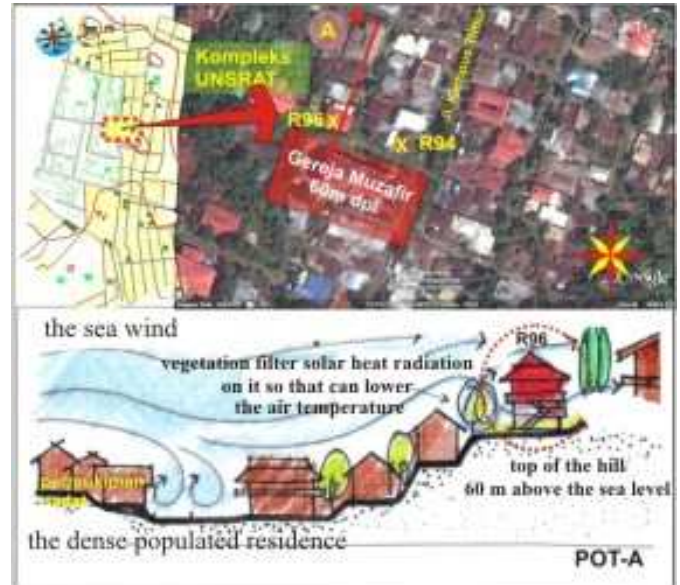


Fig. 26. Site of house R96 toward topography lies at the top of the hill 60 m above the sea level

E. Thermal Comfort Viewed from Residents' Perception

TABLE V.

THERMAL COMFORT LEVEL OF HOUSES BASED ON
STUDENTS' PERCEPTION

| Thermal comfort level | Students' perception | | | | | |
|-----------------------|----------------------|-------|----------------|-------|-------|--------|
| | A. female | | B. male | | Total | |
| | n ₁ | % | n ₂ | % | n | % |
| 07:00 AM -09:59 AM | | | | | | |
| cool uncomfortable | 0 | 0,00 | 0 | 0,00 | 0 | 0,00 |
| cool comfortable | 0 | 0,00 | 0 | 0,00 | 0 | 0,00 |
| warm comfortable | 82 | 23,10 | 55 | 15,49 | 137 | 38,59 |
| warm uncomfortable | 131 | 36,90 | 87 | 24,51 | 218 | 61,41 |
| Total | 213 | 60,00 | 142 | 40,00 | 355 | 100,00 |
| 10:00 AM-00:59 PM | | | | | | |
| cool uncomfortable | 0 | 0,00 | 0 | 0,00 | 0 | 0,00 |
| cool comfortable | 0 | 0,00 | 0 | 0,00 | 0 | 0,00 |
| warm comfortable | 22 | 6,20 | 11 | 3,10 | 33 | 9,30 |
| warm uncomfortable | 191 | 53,80 | 131 | 36,90 | 322 | 90,70 |
| Total | 213 | 60,00 | 142 | 40,00 | 355 | 100,00 |
| 01:00 PM -03:59 PM | | | | | | |
| cool uncomfortable | 0 | 0,00 | 0 | 0,00 | 0 | 0,00 |
| cool comfortable | 0 | 0,00 | 0 | 0,00 | 0 | 0,00 |
| warm comfortable | 17 | 4,79 | 11 | 3,10 | 28 | 7,89 |
| warm uncomfortable | 196 | 55,21 | 131 | 36,90 | 327 | 92,11 |
| Total | 213 | 60,00 | 142 | 40,00 | 355 | 100,00 |

Based on the students' perception of the Minahasa stilt boarding house industrial production, it can be concluded that their perception on the thermal comfort is 93.70% according to the result of thermal comfort measurement. Perception on thermal comfort between male and female students is not different significantly.

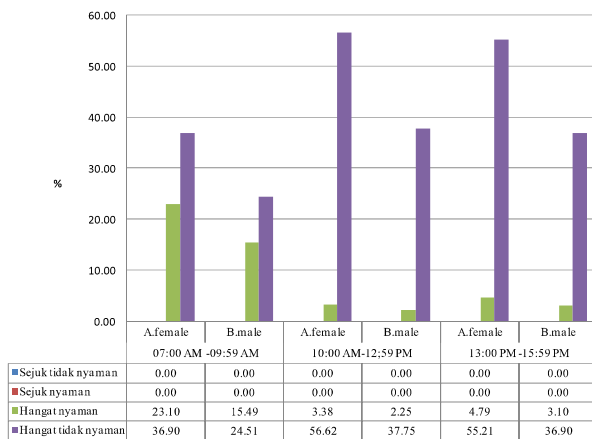


Fig.27. Diagram of thermal comfort level of units of analysis of houses based on students' perception and residents' perception

F. Concept of Thermal Comfort Development at Minahasa Stilt House Industrial Production

The development of thermal comfort of rooms at Minahasa stilt house industrial production is to be going on. Therefore it must apply the concept/guidelines of site design as follows:

1. The stilt house must be built on large enough site so that the distance between buildings is enough that is the front part of the building is 3 m, rear and left-right sides of the building is minimal 1.5⁺ m (3 m + 1.5

= 4.5 m). If the distance between buildings is less than 4.5+ m, then the location of the house must be at the sloping topography/ back of the hill and oriented toward the direction of wind..

2. The land site which has no building must be planted with vegetation (open space of evergreen yard). This is meant to lower the outdoor temperature, filter dust, and provides shading. The more the vegetation, the lower the effective temperature.

If both requirements are fulfilled, then the stilt house industrial production development can begin.



Fig. 28. Site design requirement to develop stilt house

3. The addition of room cannot block the wind, but it must direct the wind to the room. The addition of room at the ground floor can only be done at one side of the building so that the air can flow into the space beneath the house.

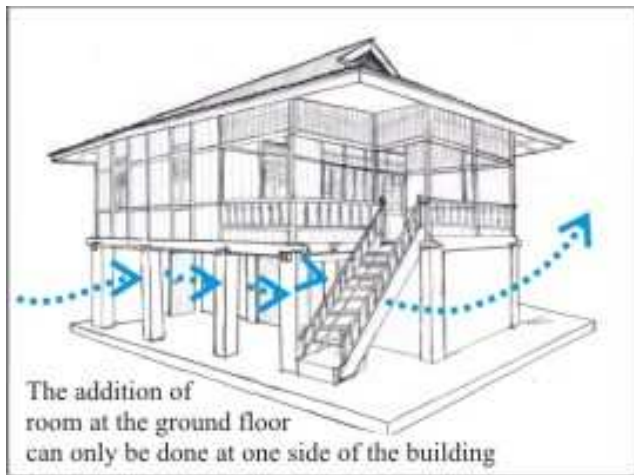


Fig. 29. Concept for the addition of room at the ground floor

4. The best building orientation is toward the east and west or toward the sun. The house oriented toward the north and south or oriented toward the wind direction, the sun light is anticipated by sheltering the building side getting direct sun light from east and west (fig 30&31).



Fig.30. Concept for house oriented toward the wind (N-S)



Fig. 31. Concept for house oriented toward the sun (E-W)

V. CONCLUSION AND SUGGESTION

- (1) Thermal comfort of Minahasa stilt house industrial production has much been developed by the owner is fully influenced by outer room design. The greatest effect is the existence of evergreen open houses yard (100%), and the location toward topography (88%), distance between buildings (84%); whereas the building orientation is not fully influential. Houses oriented toward the sun (20%) and houses oriented toward the wind (27.4%).
- (2) Residents' perception on thermal comfort of the room at the stilt boarding house is compatible to the measurement (93.70%). Houses based on the warm comfortable level are similar to comfort felt by the respondents.
- (3) The concept for thermal comfort development of Minahasa stilt house industrial production requires evergreen open space 40%⁺ and distance between buildings is 4.5⁺ m

Building and developing stilts house typical to Minahasa industrial production very potential in fulfilling economic needs of the owner and accommodation need for the students. But in the development, freshener of natural air must always be maintained optimally by applying the concept of outer room development concept of this study. If the criteria of the outer room design cannot be fulfilled, the researcher suggests not to build and develop the stilts house because the insistence to build and develop the stilts house in such condition will make the effective temperature hot and uncomfortable and this will result in the need for mechanical air freshener with the consequence of extra cost for the electric power used.

VI. SCOPE & LIMITATION OF THE STUDY

The scope of the study is related to **the outer room design** whereas **the inner room design** was not discussed although measurement of natural factor affecting the thermal comfort in the room was done in the inner room.

For the measurement of natural factor affecting the thermal comfort, measurement wasn't done to solar heat radiation and other heat sources: mean radiant temperature (MRT). This is due to limited equipment and referring to [70], [19] stating that dominant natural factors affecting human directly are air temperature, relative humidity, and

wind movement so that the researcher only measured the three factors.

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